Final Project Report to NYS IPM Program, Agricultural IPM 2002-2003

1. Title:

Preplant soil compost or fumigation, rootstock disease resistance or tolerance, and previous tree or grass rows as management factors in apple replant disease.

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4. Type of grant:

Cultural methods; sanitation; physical controls

5. Project location:

Cornell Orchards, Dryden Road, Ithaca, NY. The research site is a commercially managed research orchard, and results from this project will be immediately applicable throughout the Northeast US, and elsewhere nationally where orchard replant problems occur.

6. Abstract:

When orchards are replanted to maintain productivity, apple replant disease (ARD) often causes major problems. Soil fumigants sometimes control ARD, but biological and cultural alternatives are needed. This project evaluated disease-resistant apple rootstocks and preplant soil treatments with compost and a fumigant as methods to improve apple tree growth and productivity in a replanted orchard. After the first year of observations, tree growth on M9 was weak, and unimproved by any preplant soil treatment. For the other rootstocks, preplant soil fumigation or compost had little effect on tree growth, but location of replants where the previous tree rows had been situated substantially reduced growth of trees on M26, G16 and M7 rootstocks compared with the old grass lanes. In contrast, trees on CG210 (a.k.a. CG6210) and CG30 rootstocks grew more strongly in all preplant soil treatments, and equally well in the old grass lanes and tree rows. Soil fertility (P, K, Ca, Cu, B, pH, and organic matter content) increased substantially in compost amended soil, but this did not improve tree growth on most of the rootstocks. Populations of both beneficial (free-living saprophytic) and parasitic root-lesion (*Pratylenchus penetrans*) nematodes were greater in the old grass lane soil compared to old tree row locations, suggesting that the lesion nematode is not an important factor in ARD at this site. Based upon one year's observations in this multiyear study, it appears that CG30 and CG210 rootstocks may be resistant or tolerant to soil-borne pathogens causing ARD at this site.

7. Background and justification:

Commercial fruit growers renovate and replant their orchards periodically to maintain efficiency and productivity, and take advantage of market opportunities for new varieties. Replanted orchards are often damaged by a soil-borne disease syndrome called apple replant disease (ARD). Preplant soil applications of broad-spectrum biocides such as methyl bromide, chloropicrin, or metam sodium have provided some control of soil-borne disease, but these chemicals are difficult and expensive to apply, they sometimes fail to control ARD, and they have adverse environmental impacts. Our research is evaluating alternative ARD control strategies—host-pathogen resistance and compost soil amendments—in comparison with a likely replacement for methyl bromide fumigant—1,3 dichloropropene plus chloropicrin (formulated as Telone C-17).

Research at more than 70 farms in New York has demonstrated that ARD is a serious problem in about 60% of old orchard sites (Mai et al., 1994). Recently concluded tests of ARD diagnostic bioassays, preplant fertilizer applications, metam sodium applications, and disease-suppressive cover crops at 19 commercial orchards statewide demonstrated that preplant fumigation and suppressive cover crops failed to control ARD at more than half of the replant sites (Merwin et al., 2001). Without preplant controls, replant disease causes major economic losses in modern high-density plantings (Geldardt, 1994). This situation calls for integration and evaluation of different ARD management tactics—which is the primary purpose of our research project.

Genetically based pest resistance has been successful in combating disease problems in major crops, but there has been surprisingly little research on ARD-resistant or tolerant apple rootstocks. We recently evaluated the ARD resistance or tolerance of 941 apple genotypes representing 19 species of Malus and new rootstock clones selected for broad resistance to major pathogens, in soils from different N.Y. orchards with ARD problems (Isutsa and Merwin, 2000). Several of the new rootstock clones were quite tolerant to ARD, and we are evaluating these new rootstocks in comparison with three common dwarfing rootstocks under field conditions in this project.

A biological treatment that has provided control of woody perennial root pathogens is preplant amendment of soil with composted biomass materials (DeCeuster and Hoitink, 1999). A recent literature review revealed little research on the benefits of soil compost amendments for improving fruit-tree growth and yields in orchard replant sites, indicating that this approach to ARD control is worth investigating further.

This research followed up on previous studies for integrated management of orchard replant problems in NY. We are testing some novel but practical methods for suppressing root pathogens and promoting beneficial root-zone microbes, under field conditions in a representative commercial orchard. The ARD pest problem is widespread and seriously undermines efforts of the apple industry to renovate and modernize its orchards. Our experimental orchard for this project was planted in November 2001, after completing preplant treatments earlier that year. This progress report summarizes the first of three growing seasons for observations during the proposed work.

The methods for preplant control of ARD in this study can be implemented readily by commercial fruit growers. Compost has potential as a non-chemical alternative to chemical fumigants, and is economically competitive with other ARD control practices. Half of the rootstocks we will be testing are relatively new, but all are available from major nurseries in large quantities at prevailing prices. Rootstocks resistant or tolerant to ARD would be a very economical and sustainable alternative to soil chemical treatments for this disease complex. We have working relationships with leading apple growers in New York, and are disseminating information from this ARD research within New York and regionally. About 500 students and growers attend classes or field demonstration tours each year in the orchard where this research is located, so it provides practical demonstrations for the IPM methods involved.

8. Objectives:

1) To evaluate the resistance or tolerance of diverse apple rootstock genotypes to apple replant disease (ARD) syndrome in an old orchard site.
2) To compare soil fumigation with compost soil amendments as preplant treatments to suppress ARD and promote tree establishment and yield.

9. Procedures:

FOR OBJECTIVE 1: The test site is a commercial orchard operated by the Cornell University Dept. of Horticulture, in Ithaca NY. It was originally planted with apple around 1910 and then replanted in 1981. The second planting established poorly and exhibited many symptoms of apple replant disease (Mai et al., 1994). Trees were stunted and never attained their intended canopy volume or height; yields were low and fruit quality was generally poor. Over 20 years about 25% of the previous trees died from various causes, including winter injury and Phytophthora crown rot.

In Sept. 2001, the old trees were removed and the site was ripped to remove as many old roots as possible from the soil. Soil nutrient availability, pH, and cation exchange capacity were determined from 10 composite samples taken from each of the 12 previous tree rows and grass drive lanes. The locations of each previous tree-row were mapped precisely, and the entire site (0.5 ha) was prepared for preplant soil treatments (described below for Objective 2).

The rootstocks selected for comparison included three dwarfing apple rootstocks widely used in modern orchards—M. 9, M. 26, and M. 7—and three new rootstocks from the Cornell-Geneva (CG.) series—CG.16, CG.6210 (hereafter referred to as CG210), and CG.30. These rootstocks are roughly equivalent (relative to the widely used "M" series) in their dwarfing effect upon the scion variety. The scion variety 'Royal Empire' was grafted onto M.26, M.7, CG.16, CG.210, and CG.30 rootstocks, and NY-674 (an advanced selection from the Cornell-Geneva apple breeding program) was grafted onto the M.9 rootstocks.

The treatment arrangements and design of this project were complex, because we are testing several related factors and interactions among factors within a single field planting. Two statistically separate experiments are interspersed within the same replant site. The main experiment includes five of the rootstock clones (M26, M7, G16, CG30 and CG210) with Empire apple, planted into four preplant soil treatments (compost, fumigation, compost + fumigation, and an untreated control), and in two different positions in relation to the previous orchard tree rows (in the old tree rows vs. in the previous grass lanes). The second experiment includes trees of NY674 on M9 rootstocks, planted into the same preplant soil treatments described above.

The new tree rows were planted on Nov. 13, 2001, perpendicular to previous tree rows, enabling us to evaluate the importance of previous herbicide residues, root residues, and other biological factors that may differ within the previous tree rows vs. the previous grass drive-lanes. Tree growth is measured annually; leaf and soil samples were taken for elemental nutrient analyses and pathogen identification; bloom density and fruit set, and fruit yields will be recorded. Root growth and survival in each preplant treatment and rootstock are being evaluated using a Bartz Minirhizotron digital observation camera in Plexiglas observation tubes transecting tree root systems. The fruiting precocity induced by these clonal rootstocks and scion varieties are such that harvestable yields can be expected by the second or third growing seasons.

FOR OBJECTIVE 2: To compare soil fumigation with compost soil amendments as controls for apple replant pathogens, four preplant treatments were applied at the site as follows:

1) Shank injection of the soil fumigant 1,3 dichloropropene (78% v/v) plus chloropicrin (17% v/v) formulated as Telone C-17 (Dow Chemical Co, Midland, MI), at the rate of 400 liters/treated ha, five weeks prior to replanting apple trees.
2) Soil incorporation of a commercially available compost mixture—consisting of 40% (v/v) ground leaves and wood chips, 40% supermarket vegetable culls, and 20% pre-composted cattle and horse manure in wood shavings (Toad Hollow Farm, Nedrow, NY)—applied and worked thoroughly into the upper 30 cm soil profile in two portions on Sept. 24, 2001. This compost was selected over six other local commercially available mixtures based upon prior tests for "biological activity" at the USDA-ARS facility in Beltsville, MD. We determined the nutrient content of this amount of compost, based upon samples taken at the time of application, and compensated for indirect fertilization effects by applying a mineral fertilizer (N-P-K = 22-4-10) to all of tree rows <u>not</u> treated with compost, at a rate of 318 kg fertilizer per treated ha.
3) The third preplant treatment was a combination of treatments 1 and 2 above—compost plus soil fumigation, with fumigation completed 10 days after compost incorporation.
4) A set of control plots were left untreated, except for lime and mineral fertilizer as described.

10. Results and discussion:

The first year's growth of trees on M9 rootstocks was not significantly different among the preplant treatments, so this report will focus on the other rootstocks in our main experiment. There were substantial differences in annual trunk growth of trees on the five other rootstocks (Figures 1A-B). Averaged across all treatments, trees grew the most on CG210 and M7, and the least on M26 and CG30. These trends were consistent across preplant treatments, with no benefit from compost or fumigation compared with controls. The more important factor in tree establishment was replanting location with respect to previous tree rows and grass lanes in the old orchard at this site. Trees on M26, G16 and M7 grew substantially less when planted where old tree rows had been located from 1980-2001 (Fig. 1-B). However, growth of trees on CG210 and CG30 was not stunted in old row locations. Based upon the first year's data, it appears that rootstock genotype was more important than any preplant soil treatment or factor in promoting tree establishment at replant sites.

We analyzed soil nutrient content in each preplant treatment to determine its influence on tree establishment (Table 1). Compost amendments increased soil P, K, Ca, Cu, B, pH, and Organic Matter (OM). In the old tree row locations soil K was more available—while soil P, Ca, Mn, Zn, and OM were greater in the old grass lanes. The increased availability of essential nutrients (except K) in old grass lanes may explain the improved growth of trees in those locations, and is surprising because all mineral fertilizer applications for 20 years previously were concentrated within the old tree rows.

To determine the effects of soil fumigation, compost, and previous tree or grass row locations on beneficial and pathogenic soil microfauna, we sampled and analyzed soil for populations of an important root pathogen in apple replant sites—the root lesion nematode (*Pratylenchus penetrans*)—and for non-pathogenic saprophytic nematodes that feed on bacteria, fungi, and soil detritus, and are considered beneficial indicators of "soil health" (Table 2). In our July soil samples, Pratylenchus nematode populations were relatively low throughout the site. They were fully suppressed in the fumigation treatments, and somewhat reduced by compost (relative to untreated controls), but fumigation after compost amendments did not eliminate Pratylenchus. In October samples, Pratylenchus remained absent in apple roots of fumigated plots and low in roots of other treatments, but were rebounding in the control plots. Beneficial saprophytic nematode populations in rhizosphere soil did not appear to be suppressed by fumigation, and were usually greater in the compost treatment. Populations of both Pratylenchus and beneficial saprophytic nematodes were greater in soil samples from the old grass lanes compared with soil of the old tree rows, suggesting that turfgrass rhizosphere is more favorable than the apple rhizosphere for both parasitic and beneficial saprophytic nematodes. It is also noteworthy that newly planted apple trees grew better in the old grass lane locations despite the relatively higher populations of Pratylenchus in those sites. These observations, and the relative lack of tree growth response to preplant fumigation, suggest that *Pratylenchus penetrans* nematodes are not a major factor in the replant disease syndrome at this orchard.

Any conclusions from our first year's observations are preliminary, because improved fruit yields in the first decade of orchard establishment are the fundamental determinant of successful management of ARD. However, there is usually a close correlation between tree growth in the first several years after planting, and subsequent fruit yields, because strong tree growth in young trees provides the potential bearing surface for future yields. We will continue these experiments for several more years to determine their useful applications, but if the past year's trends are sustained, we may be able to make practical recommendations such as:

- Plant new fruit trees where the old grass drive lanes were located whenever possible

- Consider using new rootstocks such as CG30 and CG210 (CG6210) in replant sites

- Do not assume that preplant soil fumigation with Telone-C17, or compost amendments, will provide reliable control of soil-borne pathogens in all New York apple replant sites.

11. References:

De Ceuster, T.J.J. and H.A.J. Hoitink. 1999. Prospects for compost and biocontrol agents as substitutes for methyl bromide in biological control of plant diseases. Compost Science & Utilization 7(3):6-15.

Geldart, H.G. 1994. The impact of replant problems on the economics of high density apple planting. Acta Hort. 363:11-18.

Isutsa, D.K. and I.A. Merwin. 2000. *Malus* germplasm varies in resistance or tolerance to apple replant disease in a mixture of New York orchard soils. HortScience 35 (2):262-268.

Mai, W.F., I.A. Merwin, and G.S. Abawi. 1994. Diagnosis, etiology, and management of replant problems in New York cherry and apple orchards. Acta Hort. 363:33-41.

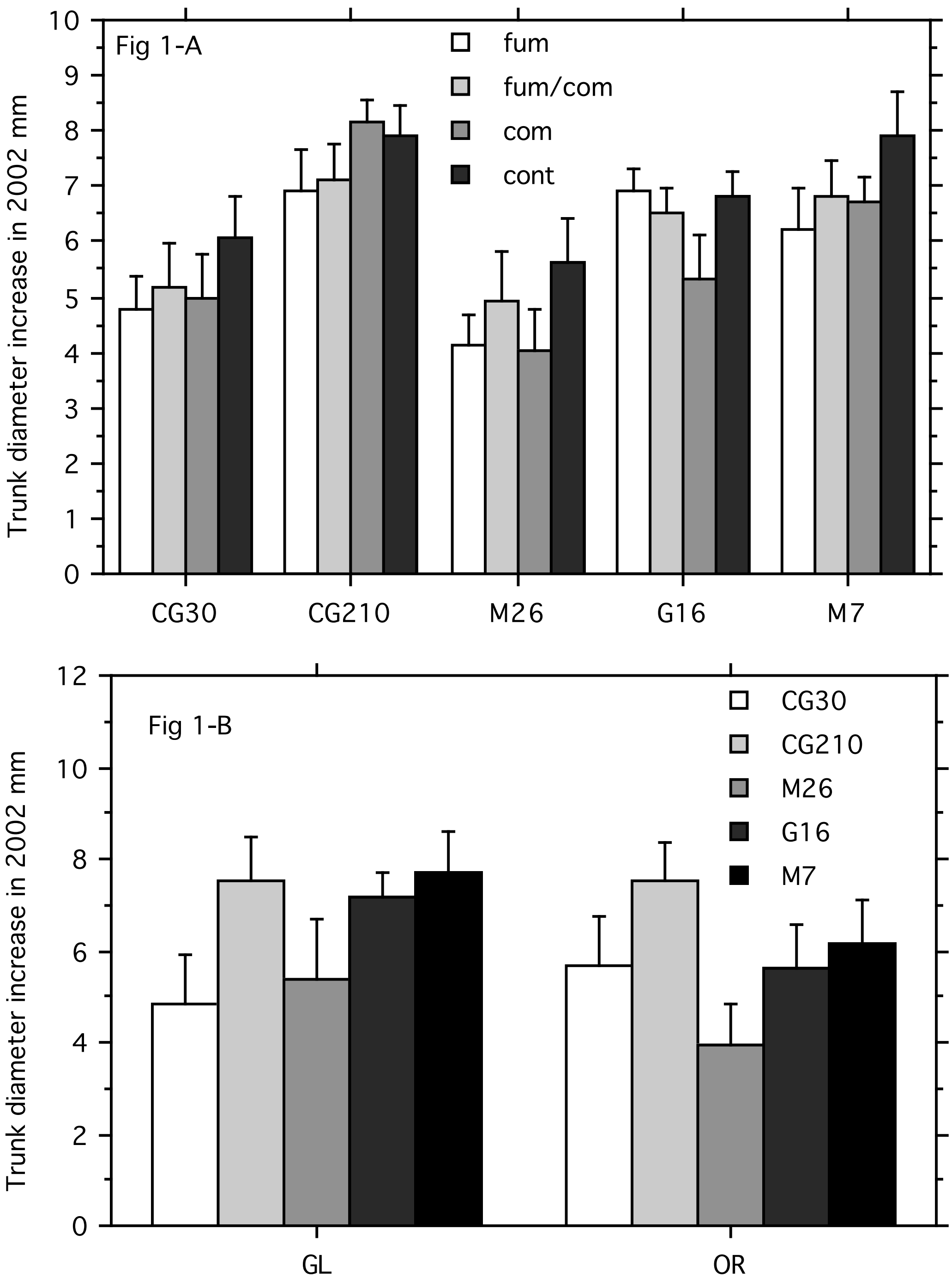
Merwin, I.A., R. Byard, T.L. Robinson, S. Carpenter, S.A. Hoying, K.A. Iungerman, and M. Fargione. 2001. Developing an integrated program for diagnosis and control of replant problems in New York apple orchards. N.Y. Fruit Quarterly. 9(1):11-15.

Table 1. Soil nutrient content (kg per ha of topsoil) in July 2002 after four preplant soil treatments in an apple replant site. Values are means of five replications per treatment. Asterisks indicate treatment means within a column are significantly different at 0.05 (*), Or 0.01 (**) probability level.

Preplant Treatments	P	K	Mg	Ca	Fe	Mn	Zn	Cu	pH	OM	NO_3	B
Control	4.3	179.9	300.9	1024	5.7	17.0	1.5	0.7	5.9	4.8	33.8	0.5
Fumigation	3.6	173.2	315.0	1043	5.5	18.9	1.3	0.6	5.8	4.7	72.1	0.5
Compost	13.8	230.3	294.3	2130	3.0	13.9	1.4	1.1	6.9	5.6	13.6	0.6
Fumigation + compost	16.0	231.4	314.1	2491	3.5	17.0	1.7	1.3	6.9	5.9	21.7	0.6
Old row location	7.9	216.1	301.9	1468	4.6	15.3	1.2	0.9	6.3	4.5	36.2	0.5
Grass lane location	11.0	191.2	310.4	1876	4.2	18.1	1.8	0.9	6.4	6.0	34.6	0.6
Treatment	**	**	NS	**	**	**	NS	**	**	**	**	**
Location	*	**	NS	**	NS	**	**	NS	*	**	NS	NS

Table 2. Populations of non-parasitic saprophytic (beneficial) and plant parasitic (*Pratylenchus penetrans*) root lesion nematodes in replant orchard root and soil samples on two dates in 2002, after different preplant treatments, and in different locations with respect to tree rows and grass drive lanes of the previous orchard. Means followed by different letters within each column are significantly different (P =0.05).

Preplant Soil Treatments	July 2002 per 100 cc soil Saprophytes	July 2002 per 100 cc soil Pratylenchus	Oct. 2002 per gram apple roots Saprophy.	Oct. 2002 per gram apple roots Pratylenc.	Oct. 2002 per 100 cc soil Saprophy.	Oct. 2002 per 100 cc soil Pratylenc.
Control	682 ns	86 a	79 b	4 ab	1800 ab	128 ns
Compost	890 ns	38 b	169 a	42 b	2424 b	64 ns
Fumigation	694 ns	0 c	17 c	0 a	1464 a	8 ns
Compost + Fumigation	778 ns	34 b	no data	no data	no data	no data
Old tree row	434 B	0.1 B	no data	no data	no data	no data
Old grass lane	1088 A	79.0 A	no data	no data	no data	no data



Figures 1a-b. (A) Increase in trunk diameter of apple trees during their first growing season (2002) on five different rootstocks, following four preplant soil treatments (fumigation with Telone C17, compost amendment, fumigation+compost, and untreated control); and (B) Annual increase in trunk diameter of trees on four rootstocks in two locations within previous grass lanes vs. old tree rows of previous orchard at this site.